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THE FUTURE BELONGS TO ASTROPHYSICS

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16. Abstract

The author presents a general history of the development of physics, in particular nuclear physics and astrophysics. He discusses the prospects for future development in astrophysics and calls for increased Soviet efforts in this area.

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In the investigation of nature, the distribution of forces /2* along the broad front of the areas of science never was and never will be uniform. At each historical stage, some one of the scientific disciplines, belonging to the great region of natural science, appears at the front of the stage and becomes the banner of scientific progress. At the present time, in the era of the scientific technical revolution, a huge army of specialists of high qualifications is occupied with investigations into the area of natural sciences and their applications; very great material resources are expended on these investigations, and for a great country the results serve as the measure of its might and the indicator of the level of cultural development. Under these conditions, the question of which scientific region will be given the leading role acquires a very definite practical sense--for it is precisely in these regions that efforts and resources must be concentrated.

From this standpoint, let us examine the complex of so-called exact sciences, studying the most general properties of matter, beginning with the scales of the microworld and ending with the scales of the universe. According to the traditional classification which has been set up, astronomy, mechanics and physics must be distinguished as independent scientific disciplines although, in reality, here we are dealing with separate regions of a single physical science, united by common scientific principles and closely interconnected due to the constant exchange of ideas and methods of investigation.

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For many centuries, astronomy was acknowleged as the leader in this group of sciences. At the early stage of the development of natural science, factual material was acquired by comparatively simple observations. In this regard, astronomy had no rivals, demonstrating the grandeur of the eternal laws of nature, in the measured rhythm of the movement of the bodies of the solar system against the background of majestic silence of the distant stellar panorama. The gradual acquisition of the basic principles of mechanics came precisely as a result of a generalization of astronomical observations in the XVIIth and XVIIIth centuries. The remaining division of physics were only just being born at that time. Only in the XIXth century after experiments became the chief tool of investigation in the natural sciences did physics appear on an equal footing with astronomy, and then--thanks to the abundance of new ideas, new facts and diverse practical applications--significantly outstripped its development.

In the beginning of the XXth century, the main lines of development of the physical sciences are crystallized with sufficient distinction. On the extreme flanks of the broad front of scientific problematics are found two very important regions, on which the bases of scientific outlook must be founded: that is, physics of the microworld and astrophysics. Initially, the first of these regions experienced rapid progress, and astrophysics--as far as general public opinion was concerned--retreated from the forefront of scientific investigation. Penetrating into the depths of the atom and the atomic nucleus, physicists first saw true mathematical harmony realized in nature. On the atomic level, the variegated /3
diversity of the external properties of matter disappeared, and we found ourselves in an area where strictness and symmetry ruled. Is it possible to imagine a more perfect construction than an atom of hydrogen, or a simpler and more fundamental phenomenon than the annihilation of an electron-positron pair? What a contrast with

the unarranged universe, with its irregularly outlined groups of stars, shreds of interstellar dust and gigantic clumps of poorly stirred stellar forms--the spiral galaxies--scattered in disorder! The main thing, however, is not in this contrast, the cause of which is the fact that the cosmos lives a hot and tempermental life (in its characteristic scales of space and time), being always in a state of rapid evolution and patterns of atoms are prepared eternally. The point is that atomic physics caused a revolution in our basic concepts of the general laws controlling the properties of matter, forcing us to re-examine the classical axioms of determinism and to again move to a description of physical phenomena in the framework of space and time. Therefore, for a long time it deserved recognition as the champion of all sciences.

These discussions are based on a comparison of the scientific values of fundamental significance. However, in order to determine the place which a science occupies in the life of a society, the knowledge of the practical value of its applications still plays a great role. In this regard, the physics of the microworld (more precisely speaking, the physics of the atomic nucleus) achieved unsurpassed records, giving birth to a weapon of total destruction and also opening new prospects for peaceful energy production. Here before us is an example of a general rule. This comes down to the fact that a truly gigantic step forward in fundamental scientific investigations always bears with it practical applications of primary importance. We note, by the way, that in practice advances in science, almost unpredictable earlier, may lie not on the main line of scientific investigation, but on its side branches. In particular, this is true for atomic technology. The possibility of using the excess energy found in the nuclei of uranium, essentially is the result of a rather random coincidence of circumstances, owing to which an increase in neutrons may take place in uranium under certain conditions. The liberation of thermonuclear energy

is a somewhat different matter. The basic idea here was derived from research in theoretical astrophysics, dedicated to the problems of the origin of stellar energy, and the possibility of its practical realization is based on the general laws of the energetics of light nuclei.

In the second half of the XXth century, the dominant direction in the physics of the microworld becomes the investigation of the properties and laws of the interaction of elementary particles. This region of science is often also called high-energy physics. The world of elementary particles proved to be very rich. In the 1950's, a whole constellation of new particles was discovered, and a number of fundamental principles controlling the laws of their interaction and decay were established. A wide range of investigations on the physics of elementary particles and the physics of the atomic nucleus became possible due to the concentration of great forces and resources in the new great scientific centers, provided with first-class experimental equipment, the basic elements of which are the gigantic acceleration devices.

At this stage in the history of science, astrophysics, developing without great external glitter, continued to enjoy its traditional respect; it nevertheless remained somewhere in the penumbra (at least as a consumer of governmental resources). The matter began to change again approximately ten years ago. On the one hand, there were found--at first almost inappreciable, and then continually more distinct--signs of a slow-down in the tempo of the development of elementary-particle physics (in complete disproportion with the growth of material expenditures). On the other hand, for these same years in astrophysics, thanks to the broad use of new methods of observation (in the first place, radioastronomical) a number of remarkable discoveries were made. The apparent peace and quiet of the universe disappeared, and we became witnesses of a multiplicity of dramatic events taking place in the stars and

galaxies. Rapidly rotating stars of gigantic density with pulsating radio-emissions, with mysterious quasars, exploding stars and exploding galaxies proved to be normal elements of the evolution of the material world. And one more recently-discovered element of this evolution, a possible echo of the distant past, is the cold waves of degenerating radio-emissions, in which the cosmos is bathed. Now this radiation is assumed to be evidence of the original explosion which gave rise to all the present stellar magnificence.

This infinitely old and constantly renewing world of cosmic objects, overwhelming in its grandeur, intensity and wealth of phenomena taking place on scales of time of from hundredths of a second to billions of years, now presents a tempting and unrivaled target for scientific investigation. The concentration of attention and efforts in the area of astrophysics is particularly natural and actual now, when thanks to the success of space technology, it has become possible to conduct observations not only from the surface of the earth but also beyond the limits of the atmosphere, and to go beyond the narrow section of the visible spectrum to the reception of the total spectrum of radiation--from gamma rays to long radio waves.

Evidently, it is possible to say that a new era in the development of science has come, in which astrophysics will occupy a key position. In order for Soviet science to be able to occupy an honored position at the very beginning of this era, we must examine the traditional evaluations of the relative value of different scientific disciplines, assembled many years ago, and advance the concept of astrophysical investigations to the forefront in our long-term scientific program.

Here, however, we need not mighty words, but real action, and /4
this action must have as its first order and primary goal the

elevation of technology of astronomical observations and the equipment resources of Soviet astronomical science to a new level. This work must proceed simultaneously in several important directions. It is necessary to continue the perfection and further development of the conventional instrumental technology of optical astronomy. The possibilities for terrestrial instruments have as yet been far from exhausted in particular if we consider the investigation of heavenly objects by means of the combined use of optical and radio-astronomical data (it is precisely in this way that the stellar objects which we call quasars and pulsars were found). New large telescopes located in regions with the best astral climates are needed for terrestrial astronomy. It is also necessary to further perfect light receivers, both photographic and photoelectric.

Large radio-telescopes and radio-interferometers have great significance for the future development of astrophysics. The necessity of covering the widest possible band of wavelengths with the provision of maximum resolution must be considered when constructing this equipment.

And, finally, the new branch of astronomical technology, to which the future belongs: extra-atmospheric astronomy, which was born only a handful of years ago. It is evident that with each year it will occupy an ever-greater position in our scientific plans and programs. If the stellar world is constructed with any measure of rationality, then the transition to the use of new space technology for observations in the infrared, ultraviolet, X- and gamma-rays, with a correct combination with the traditional methods of terrestrial optical and radio-astronomy, will in time lead to an "information explosion" which will again force us to subject many of the most fundamental concepts of the structure of matter to a thorough reexamination.

In order to accelerate this new revolution in the exact sciences, we must maximally assist the rise and perfection of astronomical

technology. The problems arising in connection with the development of the basic methods of astronomical observation, were examined in detail in the surveys of V.G. Kurt, Yu.N. Yefremov, P.V. Shcheglov, I.M. Kopylov and N.S. Kardashev, offered to the attention of the readers of "Priroda"[1].

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[1]The survey by V.G. Kurt, "Perspektivy vneatmosfernykh astronomicheskikh issledovaniy" (Perspectives of Extra-Atmospheric Astronomical Investigations), published in "Priroda", No. 5, 1972; the surveys by Yu.N. Yefremov, N.V. Shcheglov, I.M. Kopylov and N.S. Kardashev are being prepared by the authors.